HISTORY OF THE AILANTHUS SILK MOTH (LEPIDOPTERA: SATURNIIDAE) IN PHILADELPHIA: A CASE STUDY IN URBAN ECOLOGY[1]

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ABSTRACT: *Samia cynthia* (Lepidoptera: Saturniidae) is a large and colorful silk moth indigenous to China. It was first introduced into North America in Philadelphia in 1860. It rapidly established itself and extended its range to other urban areas in the eastern United States, but not to rural or suburban areas. *S. cynthia* is less common than it once was in Philadelphia. Birds, parasitoids, pollution, and plants all may have contributed to *S. cynthia's* decline. Changes in Philadelphia's urban landscape have probably reduced the availability of habitats favorable to *S. cynthia*. Whether outdoor electric lighting affected *S. cynthia* is unclear. *S. cynthia* may be considered a faunal remnant of nineteenth century urban industrial America.

The ailanthus silk moth, *Samia cynthia* (Drury), is a large and colorful saturniid indigenous to China. In North America it inhabits urban areas almost exclusively. The story of its introduction into Philadelphia, its successful establishment here, and its subsequent decline make an interesting chapter in the history of urban entomology (Stewardson 1861, Nolan 1892, Ferguson 1972, Pyle 1975).

The Host Plant

The principal host plant of *S. cynthia* is *Ailanthus altissima* (Mille.) Swingle, known by the common names tree of heaven and paradise tree (Pyle 1975). This tree is native to Asia and was introduced into Europe by the French Jesuit botanist Pierre Nicholas le Cheron d'Incarville (1706-57), who shipped ailanthus seeds there from China (Fisher 1982). The tree was planted in England about 1751 and soon was brought to North America where it was first planted around Philadelphia (Illick 1915). Originally, the tree was selected as an urban tree because of its rapid growth and tolerance of city conditions; however, it escaped cultivation and is now distributed over much of the continental United States (Elias 1980). Although the ailanthus silk moth is confined to cities, the tree flourishes in both urban and suburban areas, and occasionally in rural areas.

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Its distribution in Philadelphia today is typical of its urban pattern. It grows throughout the city, in cellar wells, poking up through iron grates in the sidewalk. Saplings sprout at the edges of parking lots and in cracks in the walls of old buildings. Specimens over thirty feet high tower over back alleys, vacant lots, and row house gardens.

Introduction of the Moth

S. cynthia has been cultivated as a silk producer in Asia for centuries (Gardiner 1982). In 1856 a missionary shipped *S. cynthia* cocoons from Shantung Province, China, to Turin, Italy. M. Guérin-Méneville, a Frenchman interested in sericulture, received progeny from these moths (Ferguson 1972).

Thomas Stewardson (1861) and Edward Nolan (1892) have described in detail the events which led to the moth's introduction into North America. Guérin-Méneville's favorable reports about the potential use of *S. cynthia* for producing silk attracted the attention of Stewardson, then corresponding secretary of the Academy of Natural Sciences of Philadelphia. In 1860 Guérin-Méneville shipped Stewardson a case containing prepared specimens of the adult, larva, and cocoon, plus various samples of the crude silk, thread, and woven cloth. Stewardson displayed these before members of the Academy. In June of that year he received two lots of eggs from Paris. The first lot failed because the eggs hatched during the voyage, but a second lot arrived in good condition a few days later. A local silk manufacturer was able to rear the caterpillars, which spun cocoons in July.

The adults from these cocoons bred and produced eggs the next month. Stewardson reared the moth in several sites around Philadelphia. Many eggs set on ailanthus trees in the country failed to produce cocoons because birds attacked the larvae, but eggs set on an ailanthus tree in a private garden in Philadelphia produced larvae that matured successfully. Larvae raised by hand indoors also did well.

Edward Nolan, then Assistant Librarian at the Academy, took over the responsibility of raising the caterpillars the next spring. He raised them in glass jars inside the Academy's library. The enterprise was highly successful but became progressively more arduous as the number of insects multiplied. Nolan took them with him when he changed jobs and moved to a chemistry laboratory at the University of Pennsylvania. The laboratory was located on Ninth Street above Chestnut Street, where a U.S. Post Office now stands. By chance, a large ailanthus grew next door to the laboratory, and its branches arched across the property line. With the

permission of his laboratory director and the neighbor, Nolan released about two hundred larvae onto the tree. Then he forgot about them.

In the winter of 1864, a little over a year after the release, Nolan noticed *S. cynthia* cocoons dangling from the tree. He counted forty. He concluded that the insect must have bred successfully in the wild, and that these cocoons represented the progeny from the individuals he had released. He stated that this tree represented the first documented point of establishment of *S. cynthia* in the area, although he could not rule out the possibility that some moths might have escaped from the outdoor colonies which Stewardson had established earlier.

After *S. cynthia's* introduction into Philadelphia, entrepreneurs interested in silk manufacturing introduced it into other cities (Pyle 1975), but no efficient way was found to reel the silk fibers from the cocoon. Although in China strong fabrics were manufactured from cynthia silk, in the United States the moth was a commercial failure (Holland 1903). In 1880, *S. cynthia* was reported to be feeding on nearly all the trees and shrubs in Central Park, New York, although only those feeding on ailanthus appeared to be healthy (Packard 1914). Holland (1903) states that *S. cynthia* was responsible for defoliating ailanthus shade trees. The current distribution of the moth is sporadic and poorly documented, occurring in cities along the east coast from Massachusetts to Georgia, and west to Indiana (Covell 1984).

The Decline of *S. cynthia* in Philadelphia

In the eight years I have lived in Philadelphia, I have yet to find a single *S. cynthia* cocoon, although I have searched ailanthus trees in the uninviting industrial habitats where the moth is supposed to occur (Ferguson 1972, Pyle 1975). In a telephone survey of Lepidopterists' Society members residing in the Philadelphia metropolitan area, only one sighting of a *S. cynthia* colony turned up. Charles Bergson reported finding numerous cocoons dangling from an ailanthus tree during 1968 or 1969; the tree was located where the Four Seasons Hotel now stands, directly across the street from the Academy of Natural Sciences of Philadelphia. In a recent survey of members of the American Entomological Society who were attending a meeting in the Academy, Joseph M. Harrison reported that in 1970 he found about fifty *S. cynthia* cocoons on a small ailanthus tree growing on the property of the American Legion Post located at 34th and Market Streets. He stated that the insect was common here forty years ago.

Tietz (1952) reports *S. cynthia* common in Philadelphia. He cites Philip Laurent. Laurent's name appears on the labels of two specimens in the

collection of Arthur M. Shapiro. One label, identifying a male, states, "Collected by Philip Laurent at Frankford, Penn, June 10, 1907." The other label identifies a female and the data are the same except for the date, July 1 of the preceding year (Shapiro 1985). Frankford is a section of the city of Philadelphia.

Parasitoids

Shapiro (1984) encountered *S. cynthia* before he left Philadelphia twenty years ago. He states:

> The moth was apparently quite common early in the century. I heard this from old-timers when I was a kid... By the late 50's - early 60's the cocoons were not at all easy to find, but tended to be highly clumped. I found them near the Frankford Arsenal, in South Philadelphia, and along Passyunk Avenue, and occasionally at the foot of Arch Street near the river and sometimes rather commonly in the old R.R. yard in South Camden, behind the J.B. Van Sciver Co. warehouse. They would not be in all those places in the same year, as a rule. The tree of course is nearly ubiquitous in the city. The parasitization rate was incredible. I believe the parasite was *Spilochalcis mariae* — check on this, as I am retrieving stuff through a lot of memory! — and some whole batches were bad — certainly the average was at least 85% parasitized. I caught single adults once at International Airport, while waiting for a bus; once on the windows of the main Lit Brothers store; and once at a shopping center near Norristown, Montgomery County, the only one I ever saw in the "country" (but downtown Norristown was pretty seedy!)

T. Pergande reared 107 specimens of *Spilochalcis mariae* Riley (Hymenoptera: Chalcididae) from 220 *S. cynthia* cocoons from New York (Packard 1914). Collins and Weast (1961) list *S. mariae* as a parasitoid of *S. cynthia*. Another *S. cynthia* parasitoid is *Eremotylus macrurus* L. (Hymenoptera: Ichneumonidae) (Hooker 1912), which was widely distributed in eastern North America including Pennsylvania at the time of *S. cynthia's* introduction (Norton 1863). Joseph M. Harrison (1980), a local breeder of saturniids, states that constant attacks by parasitoids over the last forty years have caused *S. cynthia* colonies to disappear.

Birds

Heavy infestation by parasitoids is a possible explanation for the decline in the *S. cynthia* population in Philadelphia, but other factors may also have contributed. Stewardson (1861) and Nolan (1892) stated that birds destroyed many caterpillars on ailanthus trees in the suburbs during the early attempts to rear the insect. They reported that birds destroyed fewer caterpillars feeding on ailanthus in the city, and larval survival to maturity was consequently higher in the city than in the country. These

observations suggest a possible reason for *S. cynthia's* nearly exclusively urban distribution.

Pyle (1975) noted that *S. cynthia* larvae are especially vulnerable to attacks by birds. This is because the larvae are conspicuously colored and feed together in colonies. Once birds have discovered a colony, they may hunt for the caterpillars until they have finished them all. He noted that birds are strikingly absent in the seedy habitat of New Haven's railroad yards where *S. cynthia* thrives on ailanthus, yet along railroad tracks where birds are present the moth is notably absent — even though ailanthus grows there rampantly. In New York City, the moth is found "between the bases of the Manhattan and Brooklyn Bridges, among garbage dumps, abandoned factories, and warehouses." He concluded that protection from attacks by birds determines *S. cynthia's* predilection for rundown urban habitats (Pyle 1975).

In Philadelphia, since the turn of the centry, *S. cynthia* may have lost some of its old protection from birds. The European starling (*Sturnus vulgaris* Linn.) was introduced into North America in 1890 in Central Park, New York (Bull 1964). By 1928 it had become abundant in southeastern Pennsylvania (Sutton 1928), and is now common throughout the Delaware Valley, including urban and suburban areas (Harding and Harding 1980). The mockingbird (*Mimus polyglottos* Linn.) became common more recently. Around the turn of the century it was considered a "very rare summer resident" (Stone 1894, 1958). By 1950, nesting records of the mockingbird were still extremely rare (Reynard 1953). Today it is reported to be common in suburbs all year long throughout the region (Harding and Harding 1980), and I have found it to be common in center city, Philadelphia, along railroad sidings and in residential areas. Both the starling and the mockingbird are onmivorous, with diets containing a substantial amount of insect larvae (Sutton 1928, Bent 1948).

Although the starling and the mockingbird have clearly increased in numbers, other insectivorous species may have invaded *S. cynthia's* habitat. The list of birds recorded in urban Philadelphia over the past eighty years is long (Delaware Valley Ornithological Club 1905 - 1908, Gillespie 1943, Harding and Harding 1980). I have found the blue jay (*Cyanocitta cristate* Linn.), catbird (*Dumetella carolinensis* Linn.) and robin (*Turdus migratorius* Linn.) to be common during the summer in center city, Philadelphia. The English sparrow (*Passer domesticus* Linn.), which McCook (1891) observed pecking at *S. cynthia* cocoons, may have declined in numbers (Bent 1958) but is still plentiful throughout the region. All four of these species have been observed feeding on caterpillars as well as on pupa or imagoes (Forbush 1907).

Plants

The introduction of new species of birds in Philadelphia may have reduced the number of urban habitats where *S. cynthia* could avoid predation. The introduction of new species of plants in the city, however, could have had a similar effect. *Rosa multiflora* Thunb. is an example. Peterson and Peterson (1981) have attributed the northern expansion of the range of the mockingbird to *R. multiflora.* This introduced rose is native to eastern Asia (Gleason 1952). It grows invasively, making dense thorny thickets. It produces attractive white flowers and copious red fruit. Because it provides food and shelter for animals, it has been deliberately planted for wildlife. Gardeners have grown it for its pretty flowers, and soil conservationists for erosion control (Petrides 1958). Fifty years ago the plant apparently had not yet widely escaped cultivation, as it was not reported in local floras (Porter 1903, Benner 1932, Stone 1945). It is now widely distributed in southeastern Pennsylvania (Wherry, Fogg, and Wahl 1979) and I have found it to be common in neglected, vacant urban property along railroad tracks, where it grows with ailanthus. I have found mockingbird nests in *R. multiflora* brambles in this location. *Rosa multiflora* may have suppressed populations of *S. cynthia* by providing food and shelter for its predators.

Pure stands of ailanthus trees are uncommon in the city. Plant species other than *R. multiflora* may have reduced *S. cynthia's* urban sanctuaries, but to what extent is unclear. For example, three species of trees commonly grow with ailanthus. They are white mulberry, *Morus alba* L., *Catalpa bignonioides* Walt., and *Paulownia tomentosa* (Thunb.) Steud. None of these is indigenous to Philadelphia, so any one of them might have recently invaded ailanthus' territory. On the other hand, *M. alba* and *C. bignonioides* were commercially cultivated in Philadelphia two hundred years ago (Bartram c. 1983; Darlington 1837). *C. bignonioides* grew abundantly in Philadelphia by 1818 (Barton 1818). All three species had established themselves in Philadelphia by the turn of the century (Porter 1903). Changes in urban flora may have contributed to *S. cynthia's* decline, but much of the city's weedy flora was probably already established at the time of *S. cynthia's* introduction (Bartram 1758).

Reproductive Problems

A more challenging question may not be why the moth's population declined but how it managed to survive in the first place. In 1914 Rau and Rau found an extraordinary rate of infertility among Philadelphia *S. cynthia* moths. These investigators studied *S. cynthia* as part of their

research on large North American saturniids, including *Antheraea polyphemus* Cram., *Callosamia promethea* Drury, *Hyalophora cecropia* Linn., and *H. euryalus* Bdv. They based their *S. cynthia* studies on specimens obtained from two lots of cocoons, one sent from Philadelphia and the other from New York. They conducted their observations in St. Louis.

They studied 27 fertilized *S. cynthia* from Philadelphia. These moths laid 4416 eggs. Almost half of these eggs were infertile, and half of the fertile (i.e., embryo visible) eggs failed to hatch; caterpillars emerged from only 28 percent of the eggs. Only 5 of the 27 fertilized females produced more than 100 caterpillars; 16 produced none, one or two. The investigators found that the duration of mating did not influence fertility of eggs, nor did the number of times a female mated. I quote their conclusion: "Thus we see this Philadelphia population in a sad plight in regard to their perpetuation." (Rau and Rau 1914, p. 57)

One is tempted to question these findings on the basis of possible sampling error or technical artifact. The investigators do not report how they obtained the cocoons, nor whether the cocoons were collected "in the wild." However, their studies of New York *S. cynthia* produced results which were only marginally better than those from Philadelphia. Rau and Rau were experienced breeders of Lepidoptera, and *S. cynthia* is especially easy to breed (Villiard 1969, Gardiner 1982). The other saturniids they studied showed no comparable degree of infertility or low egg viability. Finally, the authors specifically state that their chief interest was the study of moths obtained from cocoons from their natural habitats, and they also wanted to compare samples taken in different geographic areas. One can infer that they did indeed attempt to select cocoons gathered "in the wild."

Rau and Rau were unable to explain their results. Considering the industrial habitats where *S. cynthia* is found, environmental pollution would appear a possible cause for the infertility and embryonic mortality (Muller 1972). If such pollution also poisoned *S. cynthia's* enemies, it could, paradoxically, have protected *S. cynthia*; likewise, a decline in urban pollution could have contributed to *S. cynthia's* disappearance.

Urban Lighting

Predators, plants, parasites and pollutants may all have contributed to the decline in the local *S. cynthia* population in Philadelphia. Urban lighting, however, warrants consideration as well. Muller (1979) states that outdoor lighting has been the chief cause for the decline of moths in New Jersey. Ferguson (1971) blames mercury vapor lighting for the general decline in saturniids, with the exception of *S. cynthia.* Pyle (1975) considered *S. cynthia* tolerant to urban lighting but pointed out a need for

more research on the subject.

Rau and Rau (1929) conducted a series of experiments which clarified *S. cynthia's* response to urban lighting. They showed that male *S. cynthia* are able to complete long distance mating flights under urban conditions at night despite the presence of street lights. This is true even though in the laboratory at night male *S. cynthia* fly to windows exposed to outdoor street lamps. The investigators released 80 marked males half a mile downwind from females enclosed in traps mounted on the roof of an urban dwelling in St. Louis; they recaptured 44. Recapture rates were much lower when the females in traps were downwind from the release sites of the males. These data support the view that *S. cynthia* tolerates outdoor electric lighting.

Such studies do not consider other possible biological effects of street lights, such as disturbances in photoperiodism and oviposition, nor do they consider modern high-intensity vapor discharge lamps, such as mercury or sodium. Worth and Muller (1979) reported large numbers of Hymenoptera collected in light traps in New Jersey. They pointed out that urban lighting could increase or decrease saturniid populations, depending on the relative effects of this lighting on saturniids and parasitoids of saturniids. *S. cynthia's* ichneumonid parasitoid *Eremotylus macrurus* L. flies during the day and is not attracted to lights (Hooker 1912). Secondary parasites attack *E. macrurus* (Ibid). To what extent urban lighting affects these secondary parasites, and how such effects might ultimately influence *S. cynthia* populations, is a matter of speculation.

Urban Changes

Philadelphia, ecologically, is a different city than it was at the turn of the century. I have noted changes in the kinds of birds and their distribution, and changes in the local flora. But changes in the human environment also may have reduced *S. cynthia's* habitats. Philadelphia's economic base has shifted from heavy industry to service. The landscape is no longer filled with factories. Transportation by air and highway has diverted traffic from urban railroads and ports. Railroad stations have been torn down and freight yards abandoned. Oil and gas have replaced coal as fuel. Soot has diminished, and the air is clearer. The downtown area has experienced an urban revival, and sections that were rundown since the nineteenth century have been cleaned up. Bird feeding, urban gardens, and city parks have accompanied a resurgence of civic pride. In rating desirable cities in which to live, Rand McNally now ranks Philadelphia number five out of a field of 329 metropolitan areas (Halsey 1985). Philadelphia still has plenty of urban blight, but it may not be sufficient to provide *S. cynthia* the urban sanctuaries it once found here.

Conclusion

S. cynthia colonies may still exist in the city, but if so the moth must be considered rare and local. I have pointed out several possible causes for the moth's decline. These causes may have interacted in complex ways; the net effects are difficult to predict and may have varied at different points in time or in different locations within the city. Pollution, for example, may have been helpful or harmful to *S. cynthia,* depending onhow it affected *S. cynthia's* predators and parasitoids, as well as how it affected *S. cynthia* itself. Other factors may have been important but are impossible currently to assess; for example, nuclear polyhedrosis virus infects *S. cynthia* (Tanaka 1971), but the prevalence of this and other microbial organisms in *S. cynthia* populations here is unknown.

S. cynthia's early success in Philadelphia represents an opportunistic invasion of a niche that may no longer exist, or exists only in protected urban pockets like those in New Haven and New York. Sternburg *et al* (1981) have called *Hyalophora cecropia* L. (Lepidoptera: Saturniidae) a fugitive species, because it thrives abundantly in new urban areas but not in old urban areas or in rural areas. *Samia cynthia* may be compared to *H. cecropia*, in the sense that *S. cynthia* thrives in protected urban habitats until those habitats change and support its enemies. Unlike *H. cecropia*, however, *S. cynthia* survives *only* in cities in North America; it does not have a population reservoir in rural or suburban areas (Ferguson 1972). In Philadelphia *S. cynthia* may be considered a fugitive species with nowhere to go, a faunal remnant of nineteenth century industrial urban America.

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Editor's Note: Kenneth Frank (MD) is a Philadelphia physician who lives in "old" center city Philadelphia. He also is an amateur entomologist and a resident member of The American Entomological Society.

The basis of the above paper is a "popular" article Ken. Frank wrote on the virtual disappearance of the ailanthus silk moth in Philadelphia, published in a weekly neighborhood newspaper, The Welcomat, on May 11, 1983. Subsequently, he agreed to research, document, expand, and rewrite the paper for ENTOMOLOGICAL NEWS.